NASA TECHNICAL
MEMORANDUM

NASA TM X-62,251

NASA TM X-62,251

ACOUSTIC CHARACTERISTICS OF LARGE-SCALE STOL MODELS AT FORWARD SPEED

Michael D. Falarski, Kiyoshi Aoyagi, and David G. Koenig

Ames Research Center
and
U.S. Army Air Mobility R&D Laboratory
Moffett Field, Calif. 94035

(NASA-TM-X-62251) ACOUSTIC CHARACTERISTICS OF LARGE-SCALE STOL MODEL AT FORWARD SPEED (NASA) 13 p HC $3.00 CSCL 01C

N73-21924

Unclas
G3/02 69024

ACOUSTIC CHARACTERISTICS OF LARGE-SCALE STOL MODELS AT FORWARD SPEED

By Michael D. Falarski,
U.S. Army Air Mobility R&D Laboratory

Kiyoshi Aoyagi, and David G. Koenig
NASA Ames Research Center

SUMMARY

This paper presents the results of wind-tunnel investigations of the acoustic characteristics of the externally blown jet flap (EBF) and augmentor wing STOL concepts. The large-scale EBF model was equipped with a triple-slotted flap blown by four JT15D turbofan engines with circular, coannular exhaust nozzles. The large-scale augmentor wing model was equipped with an unlined augmentor blown by a slot primary nozzle.

The effects of airspeed and angle of attack on the acoustics of the EBF were small. At a forward speed of 60 knots, the impingement noise of the landing flap was approximately 2 dB lower than in the static tests. Angle of attack increased the impingement noise approximately 0.1 dB/deg.

Flap deflection had a greater effect on the acoustics of the augmentor wing than did airspeed. For a nozzle pressure ratio of 1.9, the peak perceived noise level of the landing flap was 3 to 5 PNdB higher than that of the takeoff flap. The total sound power was also significantly higher for landing indicating that turning in the augmentor generated acoustic energy. Airspeed produced a small aft shift in acoustic directivity with no significant change in the peak perceived noise levels or sound power levels.

Small-scale research of the acoustics for the augmentor wing has shown that by blowing an acoustically treated augmentor with a lobed primary nozzle, the 95-PNdB noise level goal can be achieved or surpassed.

INTRODUCTION

The acoustic characteristics of STOL aircraft are undergoing extensive investigation because of the low operating noise levels required by their operation near densely populated areas. Much of this research has been under static conditions $(V_\infty = 0)$ with small-scale models (refs. 1 and 2). This paper presents the results of wind-tunnel investigations of two STOL concepts to study the effect of airspeed and angle of attack on their noise characteristics. The investigations were performed in the Ames 40- by 80-foot wind tunnel. The STOL concepts studied were the externally blown flap

(EBF) and the augmentor wing. The models were large scale and had swept wings with spans of approximately 12 m (40 ft). The aerodynamic characteristics were also investigated and are reported in references 3 and 4.

SYMBOLS

A	engine-exhaust exit area, m^2 (ft^2)
q_{flap}	engine-exhaust dynamic pressure at the flap, N/m^2 (psf)
q_J	mean dynamic pressure at exhaust exit, $\frac{T}{2A}$, N/m^2 (psf)
q_∞	free-stream dynamic pressure, $\frac{1}{2}\rho V_\infty{}^2$, N/m^2 (psf)
T	turbofan gross thrust, N (lb)
V_J	mean velocity at exhaust exit, m/sec (ft/sec)
V_∞	free-stream velocity, knots
α	angle of attack with respect to the wing chord line, deg
δ_f	flap deflection, deg
ρ	air density, kg/m^3 ($slugs/ft^3$)

RESULTS AND DISCUSSION

Externally Blown Flap

The EBF model is shown in the wind tunnel in figure 1. The 57-percent chord, triple-slotted flap is immersed in the exhaust of four JT15D turbofan engines. The flap system is similar to systems being investigated by NASA Lewis and Langley Research Centers. The engine exhaust nozzles are circular coannular type with increased area to produce the required relation between engine diameter and flap chord. The nacelles were not acoustically treated for fan machinery or core engine noise. The wing had a span of 11.6 m (38 ft), a sweep of 25°, an aspect ratio of 7, and a taper ratio of 0.4.

The model noise was measured with 1.27-cm (1/2-in.) condensor microphones equipped with windshield nose cones. The microphones were mounted along a line under the left wing tip. The noise data were reduced to one-third octave band frequency spectra by integrating 30-sec data samples on a real-time frequency analyzer. The spectra were corrected for test-section acoustic reverberation (ref. 5) and projected to a 152.5-m (500-ft) radius by use of procedures recommended by the Society of Automotive Engineers. The perceived noise levels were computed from these data.

Effect of flap deflection.- The acoustics of the EBF model are dominated by two noise sources, the fan machinery noise and the flap impingement noise. The fan machinery noise can be seen in figure 2 as the pure tones at the blade passage frequency and its harmonics. The flap impingement noise, created by the interaction of the turbulent engine exhaust and the flap system, can be seen as the broadband noise increase with flap deflection in figure 2. The exact acoustic mechanism generating this noise is not understood. Research has shown that most of the noise is created at the flap leading and trailing edges and the noise is proportional to the sixth power of the impingement velocity.

Effect of forward speed.- Because flap impingement noise is a strong function of the velocity at the flap, any significant effect of forward speed on this velocity should change the EBF noise. Figure 3 shows the dynamic pressure distribution of the inboard JT15D turbofan exhaust near the flap (see fig. 3 inset) for several forward speeds. The general characteristics of the exhaust are not affected by forward speed although the peak dynamic pressure ratio is increased approximately 7 percent. This is a 19-percent increase in the sixth power of the flap velocity, which would tend to indicate that impingement noise would increase with forward speed.

The effect of airspeed on the frequency spectrum for the landing configuration $(\delta_f = 15/35/55)$ is shown in figure 4. The fan machinery noise decreases with forward speed because fan blade loading and inlet distortion are decreased. The flap impingement noise decreased 2 dB even though the peak velocity at the flap increased. The noise may therefore also be a strong function of jet turbulence, which would be smaller at forward speed, as well as impingement velocity. A more complete investigation of the exhaust plume is required to relate the velocity to the flap noise. The reduction in flap noise with airspeed for the takeoff flap $(\delta_f = 0/20/40)$ was approximately one-half that for the landing flap.

Effect of angle of attack.- The normal flight range of angle of attack for STOL aircraft will be 0° to 10°. The frequency spectrum for the takeoff flap at $\alpha = 0^\circ$, 8°, and 20° is shown in figure 5. The results indicate an increase in flap noise of approximately 0.1 dB/deg. As shown in figure 6 this is an increase of 1 PNdB or less in perceived noise level for the operational angle-of-attack range.

The fan machinery noise is low in figure 5 because of the high free-stream velocity ratio. At lower velocity ratios, angle of attack created inlet distortion which resulted in a 2 to 3 dB increase in fan noise for an 8° increase in angle of attack.

Augmentor Wing

The acoustic characteristics of the augmentor wing at forward speed were investigated with the large-scale model having a swept augmentor wing shown in figure 7. The wing has an aspect ratio of 8, a taper ratio of 0.3, and a quarter-chord sweep of 27.5°. The 70-percent span augmentor was powered by a slot primary nozzle. The high-pressure air was supplied by two modified Viper compressors driven by a J85 turbojet. The inlets of the compressors and the J85 were acoustically treated, as were the J85 residual-gas tail pipes.

The microphones and data-reduction technique were the same as described for the EBF. The augmentor-wing data have also been scaled to a 150-passenger, 91 000-kg (200 000-lb) aircraft assuming 80 percent of the installed thrust is ducted into the wing.

Effect of flap deflection.- The perceived noise level directivity patterns for the takeoff $(\delta_f = 40^{\circ})$ and landing $(\delta_f = 70^{\circ})$ configurations are shown in figure 8. Deflecting the flap from 40° to 70° while maintaining constant pressure ratio increased the noise in the forward quadrant by 5 PNdB. This trend is also evident in the total sound power level, as shown in figure 9. Since, at high flap deflections, the flap pressure ratio is reduced, this does not necessarily mean the augmentor is noisier at landing. The increase in power shows that the increased turning inside the augmentor generates acoustic energy. It has previously been assumed that any change with flap deflection was simply a redistribution of the sound energy.

Effect of forward speed.- The variation of sound power with forward speed is shown in figure 9. The results show that there is only a very small increase in sound power. The augmentor noise is dominated by the mixing noise of the primary and secondary flows. The very small change in power level indicates that the augmentor maintains the relative velocity constant with airspeed.

The perceived noise level directivity patterns for the landing and takeoff configurations at forward speed are shown in figure 10. The acoustic directivity shifted aft, reducing the front quadrant noise and increasing the aft quadrant noise by 1 to 2 PNdB. The changes in peak perceived noise levels were small: 1 PNdB decrease for takeoff and 1 PNdB increase for landing. As shown in figure 11, any change in perceived noise level results from a change in broadband frequency spectra, indicating a change in acoustic energy from the mixing of the primary and secondary flow in the augmentor.

Augmentor noise suppression.- The noise levels for the full-scale augmentor wing are much higher than the 95-EPNdB STOL noise goal. The Boeing Company, under contract to NASA, has investigated the acoustics and noise-suppression techniques for the augmentor (ref. 6). The results of this research are summarized in figure 12. The initial augmentor designs incorporated a slot primary nozzle. This was used as a baseline for the study. The spectra for this nozzle, which are typical of jet noise, produced a perceived noise level (PNL) of 116 PNdB. A lobe-type nozzle shifted the peak noise in the spectra to a higher frequency and reduced the PNL by 6 PNdB on a 152.5-m (500-ft) sideline. Installing the untreated augmentor shroud-flap assembly shifted acoustic energy from the high- to the low-frequency bands by reducing the jet relative velocity and creating a lower frequency acoustic source at the augmentor exit. The PNL was reduced to 104 PNdB. The inside of the augmentor was then lined with acoustic absorption material which was tuned to the frequencies containing the most annoying noise. Combining the lobed nozzle with a lined augmentor reduces the noise of the augmentor wing below the 95-PNdB noise level. With this high degree of suppression, some of the characteristics noted earlier in this presentation may change. For example, if the dominant noise source is augmentor-exhaust mixing rather than mixing of the primary and secondary flow, a noise reduction with airspeed would be expected.

CONCLUDING REMARKS

Forward speed reduced the flap impingement noise of the externally blown flap model. The reduction was 2 dB for the landing flap setting and 1 dB for the takeoff flap setting. The effect of angle of attack was to increase the impingement noise by 0.1 dB/deg. From this it can be seen that the effects of flight on an EBF model that has not been acoustically treated are small. These effects apply only for the model and engine configuration discussed herein. The presence of noise-attentuating devices may significantly alter these results.

Flap deflection has a more significant effect than does airspeed on the acoustic characteristics of an augmentor wing with a slot primary nozzle. At a pressure ratio of 1.9, deflecting the flap from 40° to 70° increased the PNL in the forward quadrant by 5 PNdB. This does not, of course, necessarily mean that the landing flap will be noisier. In fact it will probably be quieter because of the reduced throttle setting. This increase was also evidenced in the model sound power, indicating that augmentor turning not only redistributes but also increases the total acoustic energy. Forward speed shifted the acoustic directivity aft by a small amount. The changes in peak PNL were within 1 PNdB. Small-scale static acoustic research has shown that the 95-PNdB noise level can be achieved by the augmentor wing. The augmentor is therefore no longer the dominant noise source of an augmentor wing STOL aircraft. The effect of airspeed on this acoustically treated augmentor will require further investigation.

REFERENCES

1. Dorsch, Robert G.; Kreim, Walter J.; and Olsen, William A.: Externally-Blown-Flap Noise. AIAA Paper No. 72-129, Jan. 1972.
2. Dorsch, Robert G.; Kresjsa, Eugene A.; and Olsen, William A.: Blown Flap Noise Research. AIAA Paper No. 71-745, June 1971.
3. Aoyagi, Kiyoshi; Falarski, Michael D.; and Koenig, David G.: Wind-Tunnel Investigation of a Large-Scale 25° Swept-Wing Jet Transport Model With an External Blowing Triple-Slotted Flap. NASA TM X-62,197, 1972.
4. Falarski, Michael D.; and Koenig, David G.: Longitudinal and Lateral Stability and Control Characteristics of a Large-Scale Model With a Swept Wing and Augmented Jet Flap. NASA TM X-62,145, 1972.
5. Falarski, Michael D.; Koenig, David G.; and Soderman, Paul T.: Aspects of Investigating STOL Noise Using Large-Scale Wind-Tunnel Models. NASA TM X-62,164, 1972.
6. O'Keefe, J. V.; and Kelly, G. S.: Design Integration and Noise Studies for Jet STOL Aircraft. Vol. I – Program Summary. D6-40552-1 (Contract NAS2-6344), Boeing Co., May 1972. (Available as NASA CR-114471.)

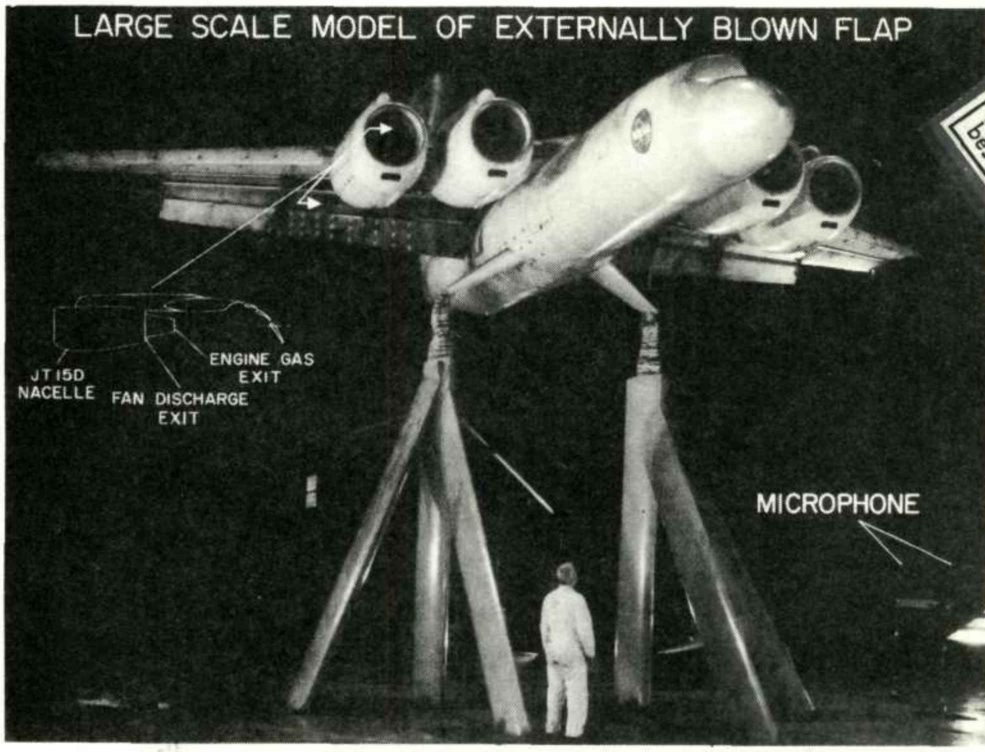

Figure 1

EFFECT OF FLAP DEFLECTION ON SOUND SPECTRA OF THE EBF
ANGLE FROM INLET = 120°, 152.5 m (500 ft) radius

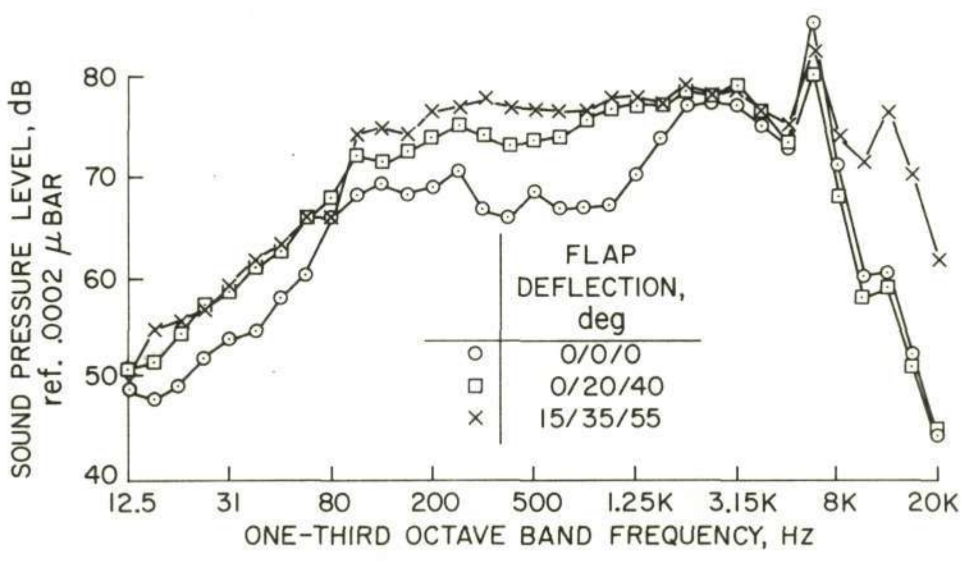

Figure 2

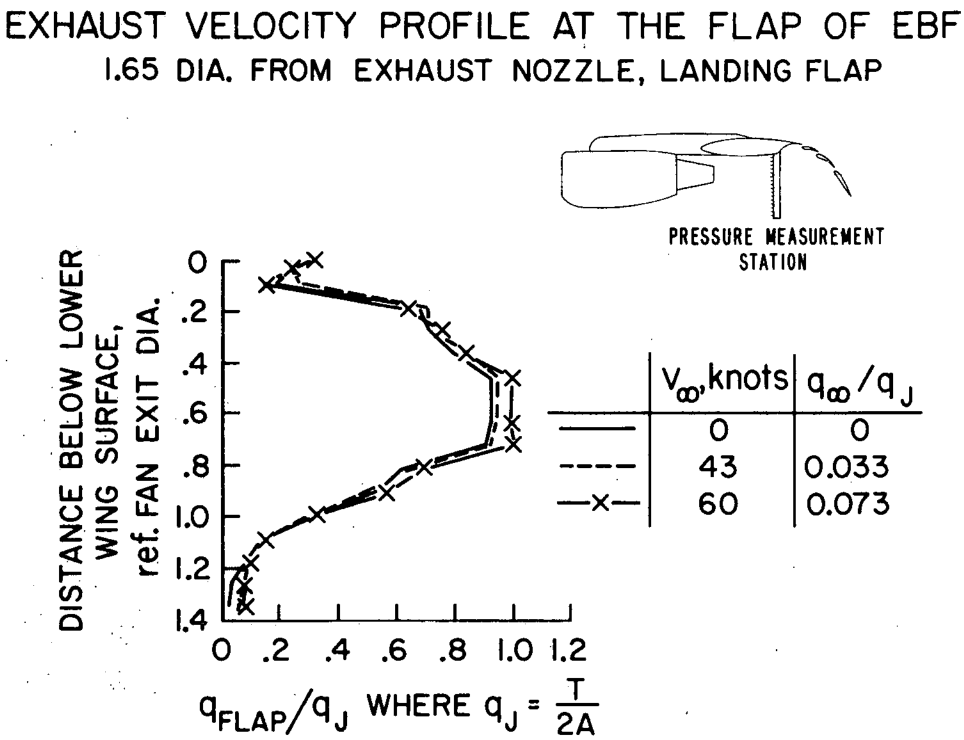

Figure 3

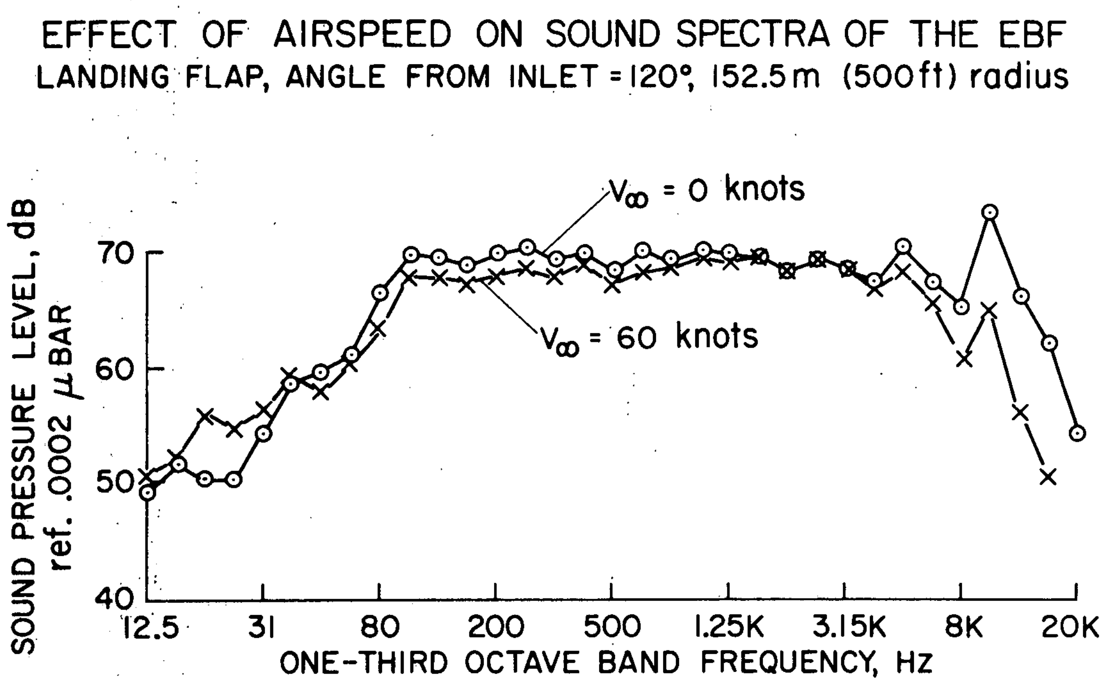

Figure 4

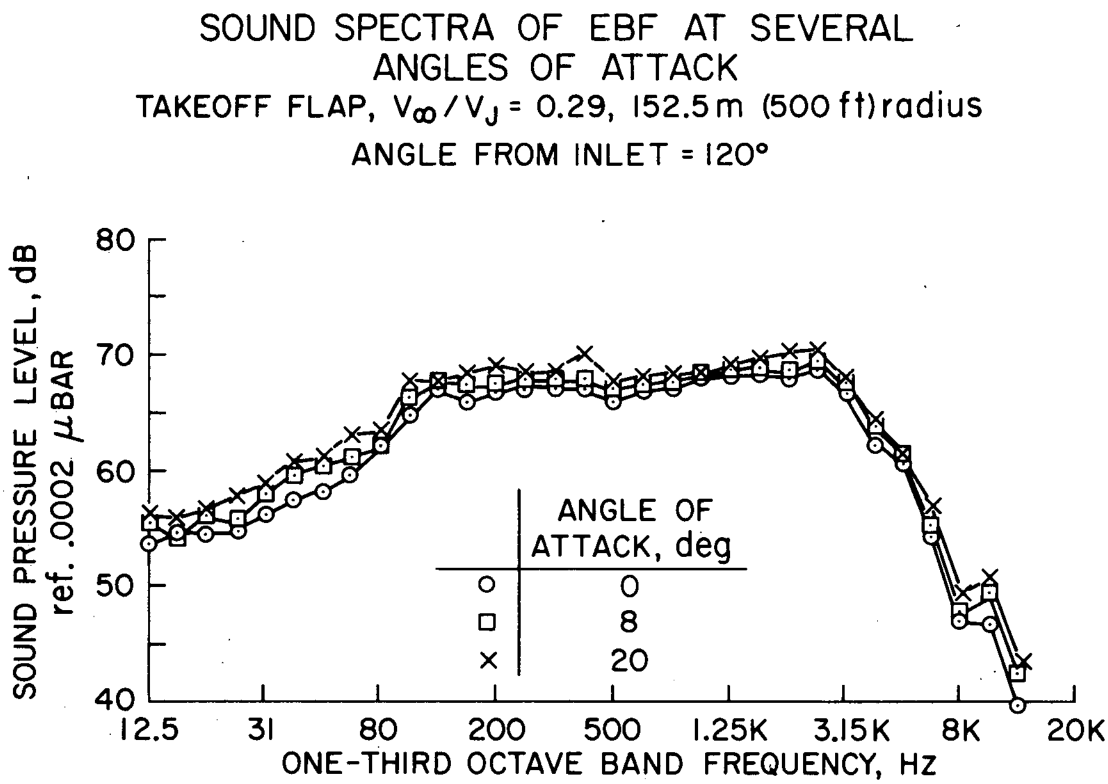

Figure 5

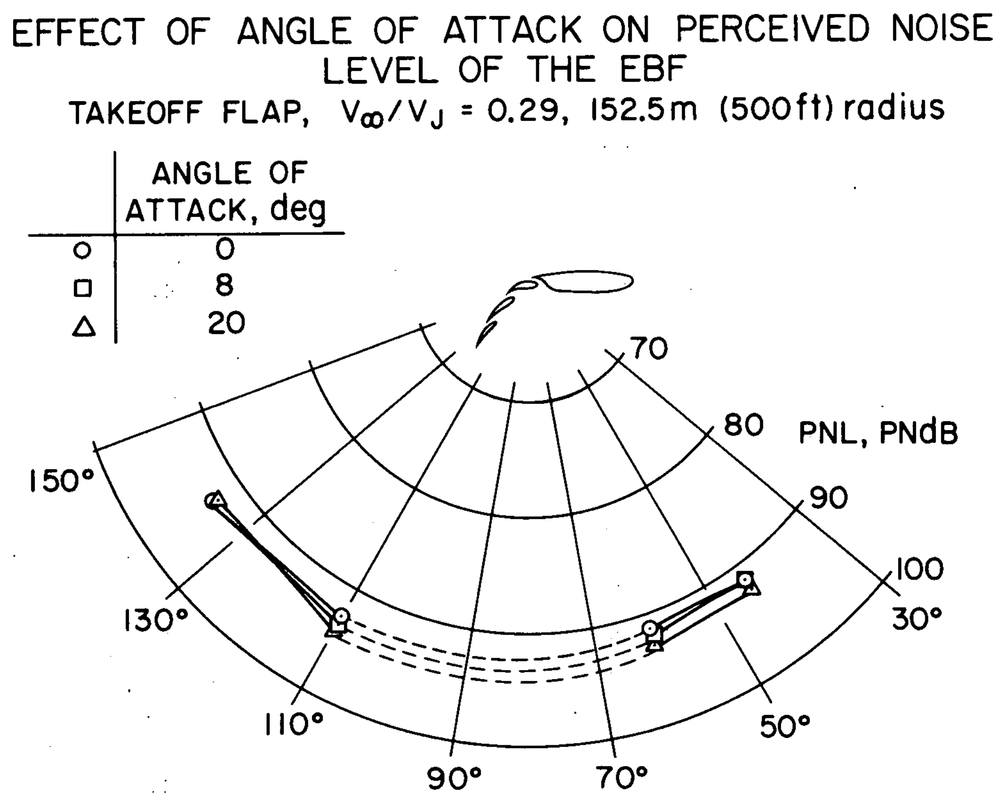

Figure 6

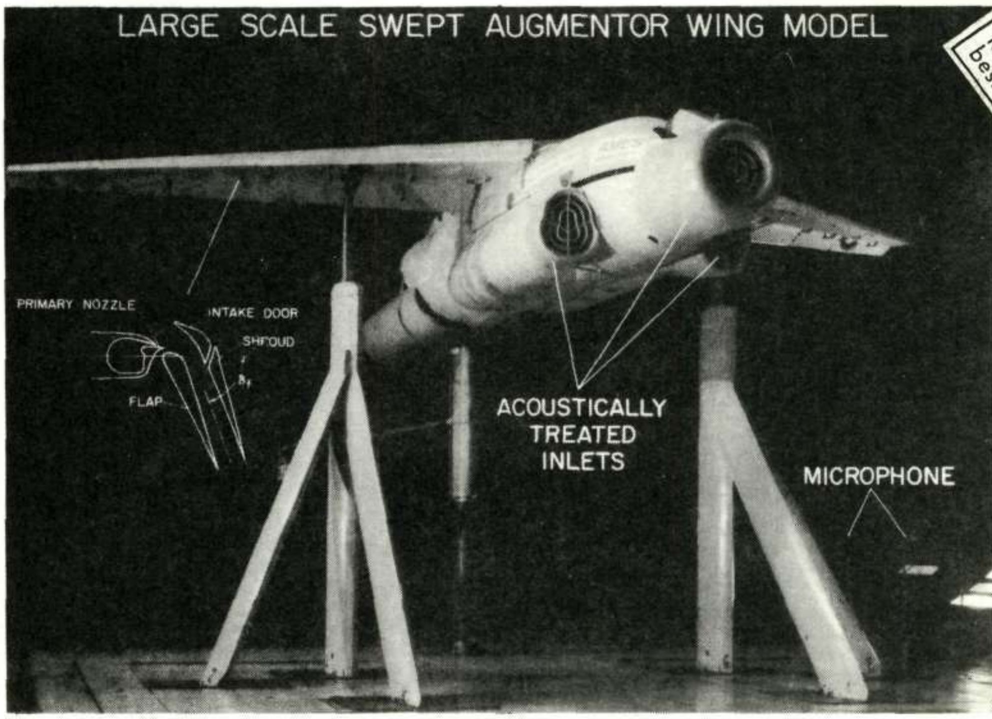

Figure 7

EFFECT OF FLAP DEFLECTION ON ACOUSTIC DIRECTIVITY OF THE AUGMENTOR WING

PRESSURE RATIO = 1.9, V_∞ = 0, 152.5 m (500 ft) FROM 150 PASSENGER AIRCRAFT

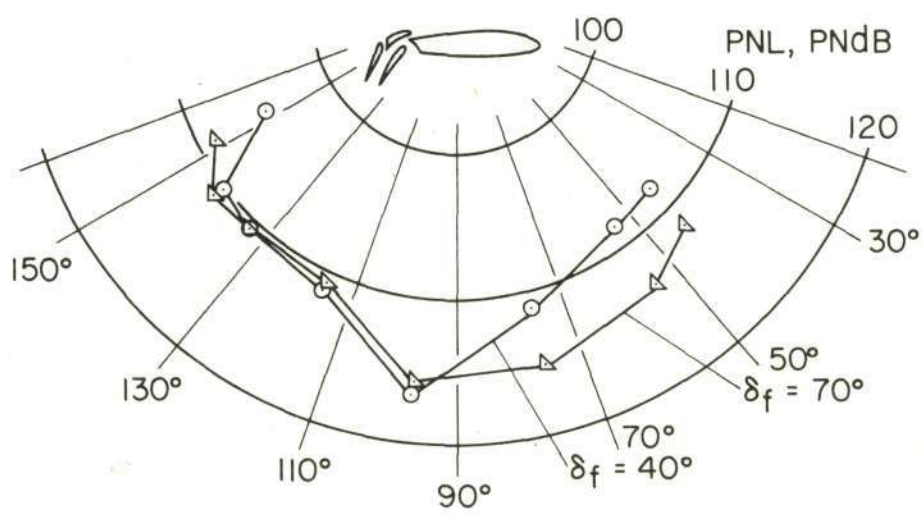

Figure 8

EFFECT OF FLAP DEFLECTION ON SOUND POWER LEVEL OF AUGMENTOR WING

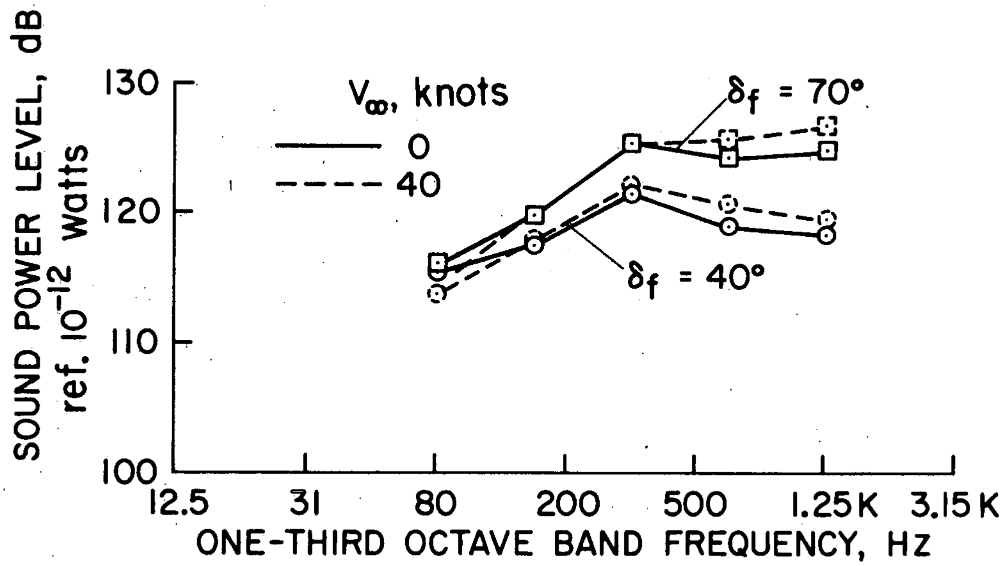

Figure 9

EFFECT OF AIRSPEED ON PERCEIVED NOISE OF THE AUGMENTOR WING

PRESSURE RATIO = 1.9, 152.5 m (500 ft) FROM 150 PASSENGER AIRCRAFT

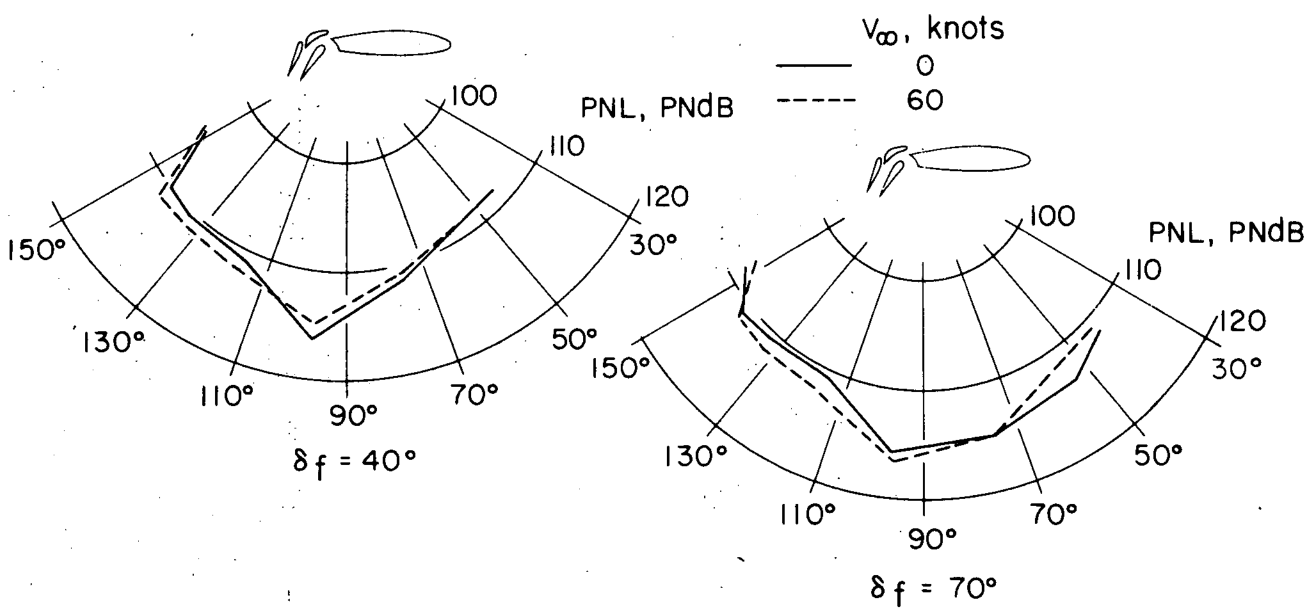

Figure 10

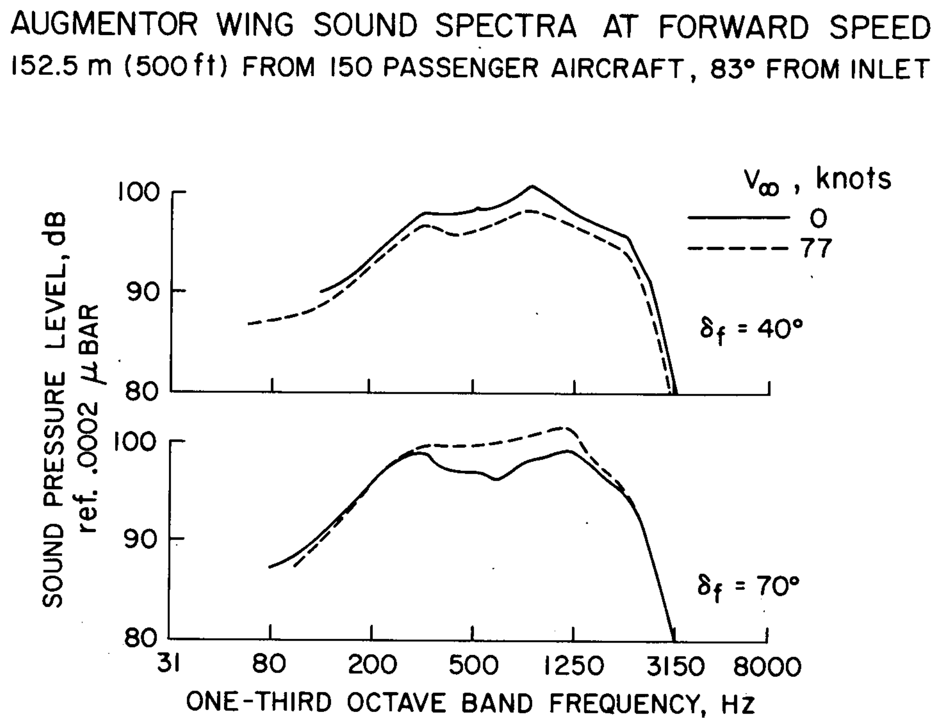

Figure 11

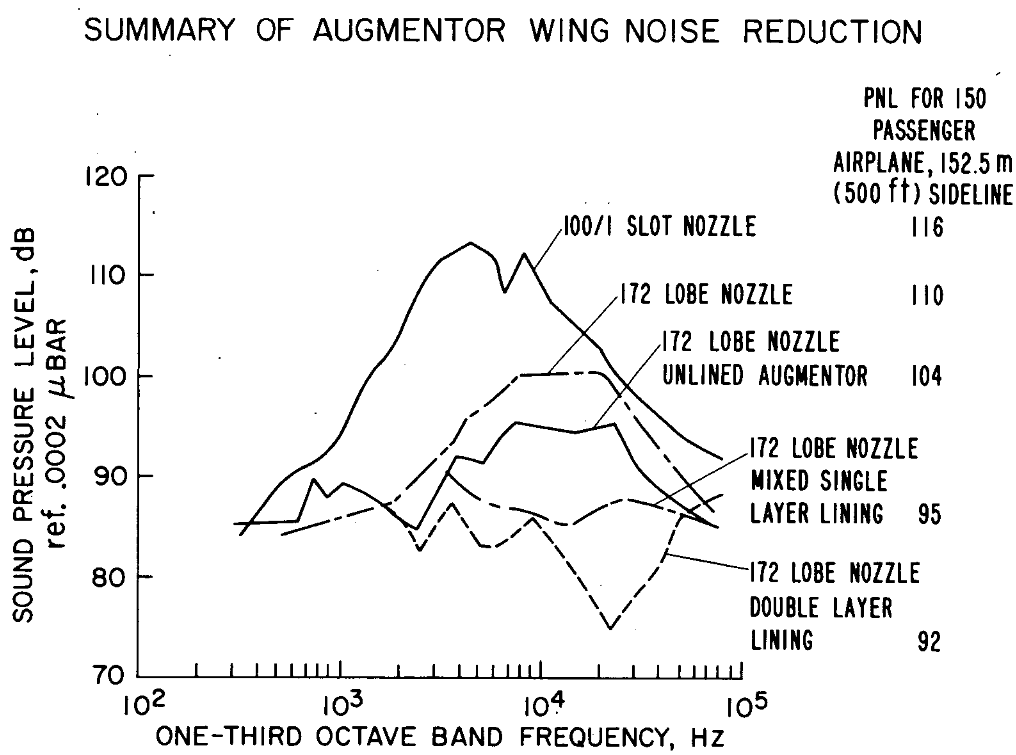

Figure 12